Astrophysics Research And Analysis

Spider: Probing the Early Universe with a Large-Scale CMB Polarization Survey

Completed Technology Project (2017 - 2020)

Project Introduction

The standard dark-matter and dark-energy dominated cosmological model (LCDM) has proven to be remarkably successful in describing the current state and past evolution of the Universe. However, there remain significant uncertainties regarding the physical mechanisms that established the initial conditions upon which the LCDM predictions rely. Theories of cosmic genesis - the extremely high energy mechanisms that established these conditions - should be expected to provide a natural description of the nearly flat geometry of the Universe, the existence of super-horizon density correlations, and the adiabatic, Gaussian and nearly scale-invariant nature of the observed primordial density perturbations. The primary objective of Spider is to subject models of the early Universe to observational test, probing fundamental physics at energy scales far beyond the reach of terrestrial particle accelerators. The main scientific result will be to characterize, or place stringent upper limits on the level of the odd-parity polarization of the CMB. In the context of the inflationary paradigm, Spider will confirm or exclude the predictions of the simplest single-field inflationary models near the Lyth bound, characterized by tensor to scalar ratios r ~ 0.03. While viable alternatives to the inflationary paradigm are an active and important area of investigation, including string cosmologies and cyclic models, early Universe models described by inflationary periods are now widely accepted as the underlying cause behind much of what we observe in cosmology today. Nevertheless, we know very little about the mechanism that would drive inflation or the energy scale at which it occurred, and the paradigm faces significant questions about the viability of the framework as a scientific theory. Fortunately, inflationary paradigms and alternative theories offer distinct predictions regarding the statistical properties of the Cosmic Microwave Background radiation. Spider will use measurements of the polarization of the CMB to search for the signature of primordial gravitational waves that are predicted within the currently favored theories of inflation. A definitive detection of this signal would provide the first direct insight into the underlying physics of inflation as well as a measurement of its energy scale. A stringent limit on the amplitude of this signal would exclude the currently favored class of inflationary models, bolstering the case for alternative theories. Spider is a suborbital Long-Duration Balloon payload housing six cryogenic small-aperture (half-degree resolution) millimeter-wave polarimeters. The frequency bands of the individual polarimeters are chosen to optimize overall sensitivity to the inflationary CMB polarization signal in the presence of Galactic foregrounds. By making extremely deep, high fidelity measurements of the entire portion of the southern sky that is relatively free of Galactic emission, the Spider data complement those of Planck (in sensitivity and control of systematics) PIPER (in frequency coverage) and EBEX (in sky coverage and angular scale). The data from Spider's inaugural flight in 2015 has resulted in high signal-to-noise maps of the southern Galactic hemisphere covering 10% of the full sky at each of 94 and 150 GHz. The payload is now being fabricated and fitted with a suite of 285 GHz cameras to extend our frequency coverage, improving our

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Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Responsible Program:

Astrophysics Research and Analysis

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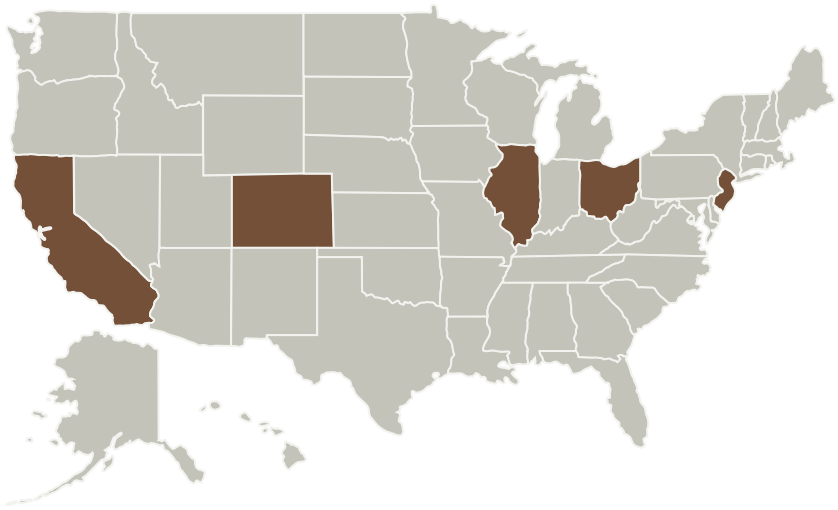
ability to disentangle the Galactic and cosmological signals. If its signature is present in the CMB, Spider's frequency coverage and fidelity to a broad range of angular scales enable the experiment to take a step beyond detection, toward the characterization of the gravitational wave induced signature in the CMB. Additionally Spider serves as a training ground for young scientists, including 16 graduate students (9 female, 7 male).

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Princeton University	Supporting Organization	Academia	Princeton, New Jersey

Primary U.S. Work Locations	
California	Colorado
Illinois	New Jersey
Ohio	

Project Management

Program Director:

Michael A Garcia

Program Manager:

Dominic J Benford

Principal Investigator:

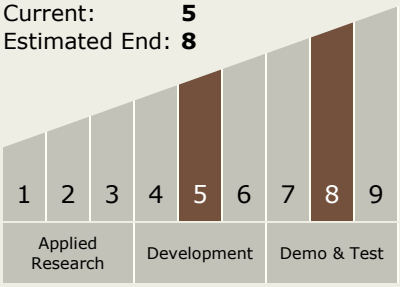
William C Jones

Co-Investigators:

John E Ruhl
James J Bock
Calvin B Netterfield
Johannes Hubmayr
Jeffrey Friedland
Aurelien A Fraisse
Jeffrey P Filippini

Technology Maturity (TRL)

Start: **5**
Current: **5**
Estimated End: **8**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.1 Remote Sensing Instruments/Sensors

Continued on following page.

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Technology Areas *(cont.)*

- TX08.1.1 Detectors and Focal Planes

Target Destination

Outside the Solar System